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Developing a Methodological Taxonomy of EER papers

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INTRODUCTION

Engineering Education Research (EER) is a wide and rich field of investigation [1]. It covers research on learning and teaching in all engineering disciplines as well as in the supporting disciplines, like physics, chemistry, computing and mathematics, which form the scientific basis of engineering research. Moreover, EER draws on theories and research methodologies from social sciences, like education, psychology and sociology to investigate the many-faced aspects of learning and teaching engineering. In order to get a better overview of the whole field, there is a need to look at both *what* is being researched and *how* the research is carried out.

The authors of this paper met in connection to a series of meetings arranged by the SEFI working group EER and a series of workshops organised by Line B of the EU project EUGENE, and decided to collaborate on the construction of a taxonomy for EER from a European perspective. The overall aim is to develop a taxonomy for the *how aspect* of EER. More specifically, we aim to identify what kind of theoretical frameworks and research designs that are being used, what kind of data that is collected and how it is analysed in EER papers. Our current analysis focuses on published papers in two major European EER forums: European Journal of Engineering Education and the EER track in the SEFI conference, but the taxonomy can obviously be used to analyse any other EER papers. We hope that this work will better reveal the richness of the field, but also highlight approaches that could be used more often in EER. Moreover, the results can be used to inform authors about differences between various publication forums, and emerging methodological trends in research. Finally, we will also look at how different aspects of research have been reported in EER papers with a view to providing suggestions for improving research reporting.

In this paper we describe the taxonomy and how it was developed. The results of the analysis will be reported elsewhere.

1 CONSTRUCTING THE TAXONOMY

There is a large body of research on categorizing research in engineering education. Wankat [2,3] analysed papers published in the Journal of Engineering Education (JEE) in 1993-2002, and categorized the papers based on the topic of research, theoretical framework and what kind of data that was collected. Additional themes in the analysis were gender distribution of authors and citation analysis. Whitin and Sheppard [4] also focused on JEE papers (1996-2001) and analysed research topics using a coarser classification than Wankat. They also discussed characteristics of quality papers. Osorio & Osorio [5] analysed three years of papers in JEE and EJEE and mainly investigated author data (country, profession, and affiliation) but also the generic nature of the paper (e.g. project report, research report, case study, or survey), as well as the research topic. Osorio [6] augmented this work by discussing various publication forums for EER papers. In 2007, Borrego [7] analysed 700 abstracts from four NSF-funded Engineering Education coalitions, looking at the target groups of the analyses, the focus areas of the generated change, and the nature of the contribution. Jesiek et. al [8] analysed 2173 papers published in major EE journals and conferences between 2005 and 2008. They investigated more closely a subset of 885 papers that included analysis of empirical data, and focused their analysis on the authors' origin, collaboration between authors, research topics and their co-occurrence in papers. In 2010, de Graaff and Kolmos [9] analysed papers published in EJEE in 2008-2009 and presented a classification scheme of research methods that were used.

Within Computing Education Research (CER) there have been many similar efforts to categorize research, independently of the work undertaken in the EER field. Fincher and Petre [10] identified 10 main areas of CER. Pears, Seidman et. al. [11] complemented this work by



proposing a new framework which also included a coarse evaluation of the significance of the study. Simon [12] developed a categorization scheme, which included research topic, scope of investigation and nature of the contribution. Malmi et al. [13] presented a new multi-dimensional categorization scheme, which mainly captures the research goals and process. Kinnunen et al. [14] analysed papers CER papers from the perspective of the didactic triangle, i.e., whether the research concentrated on contents/goals, students, teachers or some relation between them.

The previous attempts to categorize EER papers have quite heavily focused on publications in the US. This work has mainly focused on research topics, authors and citation data, and thus built a good picture of the main research areas and foci of interest, as well as the research community. On the other hand, the research process, i.e., how the research has been carried out, has received relatively little attention. In this paper, we therefore focus on this aspect of research. We aim to build a better understanding how EER is carried out and how it is reported, by developing a methodological taxonomy of EER papers. We hope that this knowledge helps us to disseminate and promote high quality research practices in the EER discipline. The papers analysed using the taxonomy were drawn from two major European publication forums in EER: The European Journal of Engineering Education (EJEE) and the EER track at the SEFI conference.

In developing the methodological taxonomy, we have drawn on previous classification schemes. Malmi et al. [13] analysed the CER literature using a multi-dimensional framework, focusing on five questions: 1) “What theories/models/frameworks were used?”; 2) “What was the overall goal of the research – to describe a novel contribution, to evaluate it or to formulate something new?”; 3) “What research design was used?”; 4) “What kind of data was collected?”; and 5) “How was the data analysed?”. We adopted all these dimensions except for the generic goal dimension in this work. For data collection dimension we listed all different data sources that we find. For the data analysis dimension we used a coarser classification scheme based on de Graaff and Kolmos [9]. In addition, we adopted, although in a simplified form, the nature dimension from Simon [12] to describe the generic type of the paper. Finally, we added a new dimension to explicitly describe the way in which the research is reported. Thus, after the meeting at the EER Summit in Leuven 28-29 October 2011 we agreed on the following main categories for the EER taxonomy:

- General nature of the paper
- Theoretical background, on which the paper is built
- Types of research questions and research paradigm or general research design how they are addressed
- Type of collected data and subjects of study
- Methods used to analyse the data
- How these aspects of the research process have been reported in the paper.

Given that this kind of analysis involves researchers applying a degree of subjective judgement as they analyse each paper (by contrast with procedures like citation or affiliation analysis that by their nature are more objective) a two-stage online calibration process was built into the procedure so as to achieve inter-rater reliability between the authors. Thus, after all authors had been involved in defining the original categories, the same batch of 8 EJEE papers was analysed individually by all participants and subsequently discussed in 4 pairs (using email, VOIP and Google Docs) to get consensus within each pair. When the consensus results of the 4 pairs were compiled in a database and compared, we identified several sources of ambiguous definitions, and problems of interpretation. These issues were considered together by email, and a new revised classification scheme was derived. The whole process was repeated with a different batch of EJEE papers.



Finally, once an acceptable level of inter-rater reliability had been achieved between the 4 pairs of researchers, each pair then proceeded to apply the taxonomy to different batches of EJEE and SEFI conference papers to provide the final extended run of data gathering. The results of the analysis will be published elsewhere.

2 THE METHODOLOGICAL TAXONOMY FOR EER

The proposed taxonomy categorizes research in six dimensions. In principal, we consider the dimensions independent of each other, but we recognize that certain research paradigms do tend to prefer certain types of data collection and analysis methods.

2.1 Nature Dimension (NT)

The nature dimension tries to capture the general character of the paper as a whole. We categorize the nature dimension, as follows:

- *Empirical* paper is a paper, which has the basic elements of empirical research, including clear data collection, analysis and reporting results. The paper may or may not have hypotheses. Data analysis may be based on quantitative or qualitative or mixed methods.
- *Case report* describes a novel educational setting, such as a new teaching method, assessment method, learning resource, learning specific software, *etc.* The focus of the paper is in describing the new contribution. There is no evaluation, or the evaluation is very shallow, typically reporting some student results, student feedback and/or teacher's experiences with no clear research setting (such as comparison to previous year). A case report typically has a limited scope, related to some specific course and the research setting and method aspect of the paper is vague – the focus is on the novel thing, whether it be teaching method, software or something else. Usually, the focus of the paper is to improve practice.
- *Position paper / Proposal* is a paper where the authors want to raise some issue for discussion among EER community or propose something new to be considered in engineering education practice or EER, such as new course or curriculum requirements.
- *Theory paper* discusses theoretical aspects of teaching and learning, for example, compares some learning theories in some context. The paper is based on theoretical discussion and argumentation and has little or no empirical data to support its claims.

We will not differentiate whether the nature of the paper is explicitly stated or implicit, as this is basically our interpretation of this issue. All papers have some nature. We, though, do not analyse editorial papers.

2.2 Explanatory Framework Dimension (EF)

Neither research nor practical development takes place in isolation. We are building on previous work by other researchers and practitioners. This is the basic premise of all academic work. Scholarly work should also always recognize the premises of one's work and methods. Equally important is to give credit to others' work on which we are building our own work by mentioning this in the text and properly referencing their publications and works. The explanatory framework dimension aims at making it visible how the target publication is linked to previous work [15]. We limit our investigation to such conceptual constructs that we expect to be known in a wider community of EER researchers. These constructs, which we call Explanatory Frameworks (EF), can be, for example, the following:



- *Theory* can refer to well-established theories, such as constructivism, situated learning, or cognitive load theory.
- *Model / framework / taxonomy / formal construct* refer to established conceptual constructions, which are not generally called theories. Some examples could be Bloom's or Solo taxonomies, concept maps, IEEE curriculum definitions, pedagogical patterns.

Very often papers build on previous research, which does not have an established widely known status, in various ways. These could be, for example, using previous work as motivation, extending previous research to a new data set or reanalysing previous data sets in a new way, using previous results as a starting point for new research or applying a methodology, which was developed in another paper. To simplify the analysis we will not classify the latter types of references, but consider only such EFs that we consider well-known within EER community. Though, at the same time we recognize that “well-known” is an ambiguous concept, and thus needs to be negotiated.

We also do not list links to technical tools or frameworks. There is a multitude of such applied in EER, as engineering is about designing, implementing and applying technologies. Neither do we classify methodological references here, such as phenomenography, content analysis or various statistical tests. The methodologies are captured by other dimensions.

Each EF is accepted on face validity. If the authors claim they are using it, we do not question this, as we can analyse in reasonable time only the publication we have. We will not report EF's, which are not explicitly mentioned in the paper, i.e., we will not try to interpret from the paper whether the work is based on some EF.

2.3 Research Strategy Dimension (RS)

There are many different ways how research is carried out. Here we differentiate the general research design from more detailed level data analysis methods. The former captures the choice of research questions and how they are generally approached, while the latter concern the concrete analysis methods used in processing collected data. Here we face a problem which terminology we should use for the wider design of the research. In some contexts, we could use here either term *research paradigm* or *research approach* but these are not used in all cases we cover, and especially the term paradigm is a too wide concept for us. On the other hand, the term *research design* typically refers to a rather detailed description of the research setting. Malmi et al. [13] used a term *research framework*: Research framework “...is an overall orientation or approach that guides or describes the research, as opposed to a specific method or technique. A research framework may have associated theoretical, epistemological, and/or ontological assumptions (e.g. phenomenography), may prescribe or suggest the use of particular methods (e.g. grounded theory), or may simply be a descriptive term for a kind of research activity that has certain characteristics (e.g. action research, case study). Not all papers will have a research framework.”

A similar dimension has also been proposed by several other researchers, though with different names: Case and Light used the term *emerging methodologies* [16], and Chism used *research strategies* [17]. Also Merriam [18], Creswell [19], and Denzin and Lincoln [20] present a similar type classification for methodologies. We will adopt the term *Research Strategy*, instead of Research Framework, to avoid confusion with Explanatory Framework.

We propose the following set of strategies, though we recognize that the list can be expanded.

- Action Research
- Case Study



- Constructive Research²
- Delphi
- Ethnography
- Experimental Research
- Grounded Theory
- Phenomenography
- Phenomenology
- Survey Research

A paper may have more than one research strategies. On the other hand, a paper may not have any research strategy that we can identify. Each explicitly mentioned research strategy will be accepted on face validity. If the authors claim they are using it, we will not question this.

2.4 Data Source Dimension (DS)

Data collection implies what kind of data has been used in the empirical part of the work. Most papers have at least one data source, but very often include several. Examples of categories in this dimension include the following (the list is not exhaustive): students' submitted work (essays, project reports, learning diaries...), examinations and tests, questionnaires, instruments, interviews, observation data, databases (e.g. study register data), software log data, researchers' own experiences (e.g. "lessons learned"), and literature (e.g. literature reviews, meta-studies).

An instrument is a special case of a questionnaire. It is a psychometrically validated questionnaire, which is used to measure some aspect of human behaviour, such as Myers-Briggs personality test. We list such instruments, if encountered, as they are useful tools in many aspects of EER and we wish to promote their wider application, instead of building similar tools ad-hoc.

Typically most papers report some of researchers'/teachers' own experiences or occasional observations. However, we will report them as data source only if their share of the paper is significant compared to other collected data.

Finally, we will register what is the *scope of data collection* (as a whole), i.e., has it been carried out in the individual level, group level (like classroom, student group in one course/unit, whole course/unit), institution level (curriculum, program, university, ...) or multi-institutional level (many universities, whole country, ...).

2.5 Data Analysis Dimension (DA)

The data analysis dimension will describe how empirical research data are being analysed or what other means are used to draw conclusions in the paper. Most papers feature at least one kind of analysis method. If a paper has a research framework, the framework often directs the analysis methods that are used. However, the same analysis method can, of course, be found in a paper that is applying some other framework or has no specified research framework at all. The number of possible analysis methods is extensively large and we need to gather them into rough categories. We will apply the following categories to cover the data analysis method dimension:

- *Quantitative simple* includes descriptive statistics and cross tabulation and graphics.
- *Quantitative complex* denotes any form of statistical methods exceeding simple descriptive statistics, such as statistical tests, correlations, regression analysis, factorial or cluster analysis, data mining techniques, ...

² Research that aims to demonstrate and/or evaluate the feasibility of a proposed idea (concept implementation; proof-of-concept research).



- *Qualitative simple or not-specified* includes qualitative analysis, which only includes identifying important themes, topics or items of interest in qualitative data like interviews without specifying a method or structure. This category will also be used in cases where it seems that some method has been applied, but due to missing description we cannot know what it was.
- *Qualitative enhanced* denotes any qualitative methods, which have a clearly specified analysis process, reported to such aspect that that it could be repeated.
- *Other* includes other methods, like formal proofs.
- *None*, which includes authors' reflections like "lessons learned".

A paper can include several of above methods and we will list all that we recognize regardless of whether they are explicitly stated in the paper or implicitly included. Based on that we can later on derive whether the paper is a quantitative, qualitative or mixed methods paper.

2.6 Reporting Dimension (RP)

Reporting the research setting and process clearly is a central part of good scientific communication. We will make observations on the text on three following aspects: *research questions/goals*, *methodology* and *discussion on validity/reliability/generalizability* of research. We look at how these are reported in the text. Are they explicitly emphasized, such as using subtitles, bullet lists or written in italics? Or, are they implicitly included in other text, such as research questions are in introduction and discussion on validity is within the general discussion section? Or, if we cannot find some of them at all with reasonable effort.

3 DISCUSSION

When presenting this taxonomy, we must ask ourselves, who could benefit from this? We see several aspects that could support building the EER community. First, a general awareness of the richness of the field will be increased, if we can show in numbers how various research paradigms are applied in the field, what kind of theories are used as frameworks, and how data is analysed. Moreover, the taxonomy could be used as a measurement tool to reveal differences between various publication forums, thus giving suggestions for authors where to submit certain types of papers. Furthermore, it could make visible hidden trends or emerging research paradigms in the field. By clarifying the difference between case reports and research papers, we can also point out how scientific level of papers should be increased when we aim at more generalizable results and deeper insights.

The taxonomy could also be used as a reference when the publication forums are defining review criteria for different types of papers. At the moment we see it clearly problematic that the review criteria in many conferences and also in some journals do not give clear enough guidelines both for authors and for reviewers what is expected for the papers.

Finally, as EER is gradually gathering recognition as an emergent field moving from the margins to the mainstream [21, 22], a taxonomy can help to provide a map of the terrain for new scholars entering the field. We expect the results of this analysis to provide us with data that supports the goal of building recommendations, how to enrich research practice and improve scientific writing in the EER community.



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